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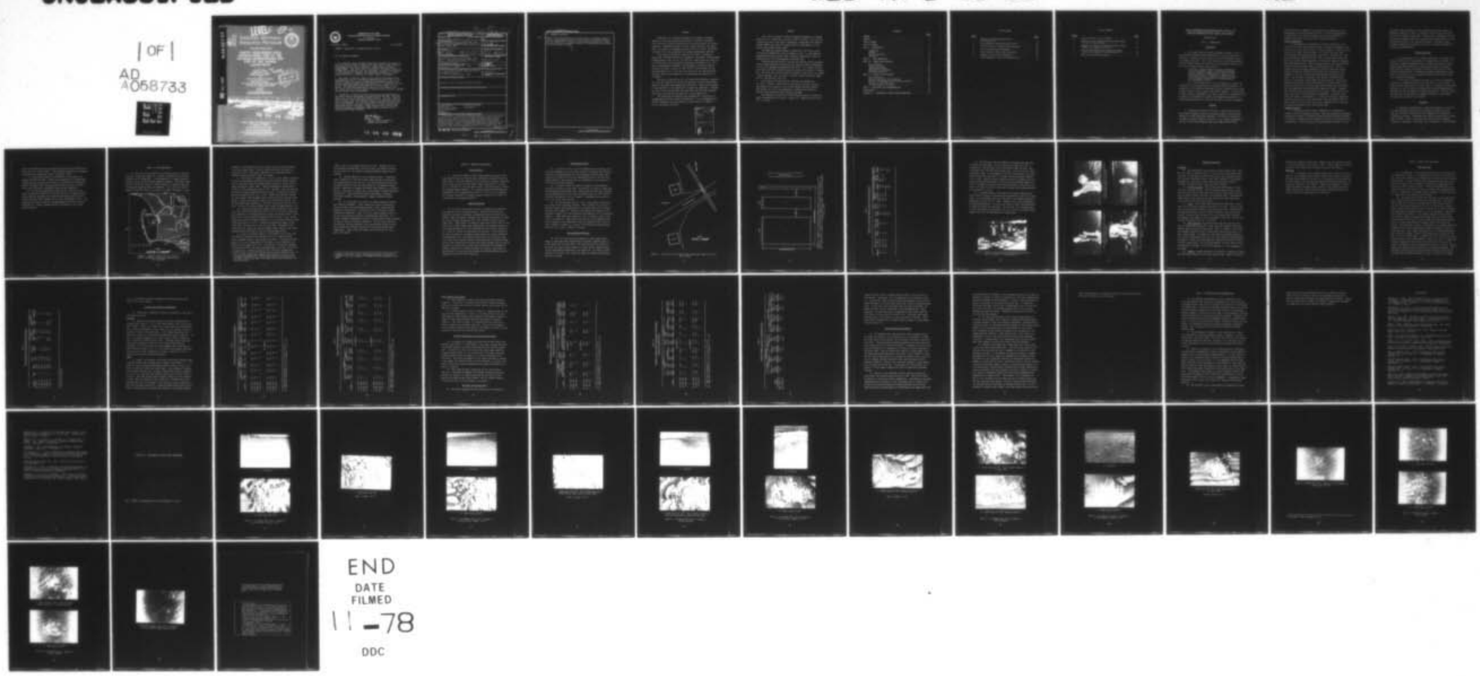

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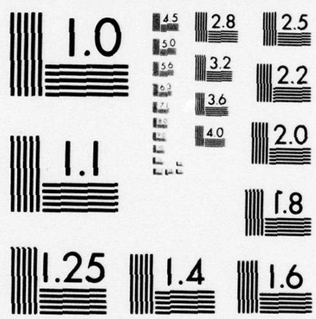

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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-33

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, PORT ST. JOE SEAGRASS DEMONSTRATION SITE PORT ST. JOE, FLORIDA

SUMMARY REPORT

by

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July 1978

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 4E03

Monitored by Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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SUBJECT: Transmittal of Technical Report D-78-33

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1. The technical report transmitted herewith represents the results of one of the research efforts (work units) under Task 4E (Aquatic Habitat Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4E was part of the Habitat Development Project of the DMRP and was concerned with the development, testing, and evaluation of the environmental, economic, and engineering feasibility of using dredged material as a substrate for aquatic habitat development.

2. This report of Work Unit 4E03 entitled "Habitat Development Field Investigations, Port St. Joe Seagrass Demonstration Site, Port St. Joe, Florida" presents the results of seagrass establishment research conducted on submerged dredged material deposits in St. Joseph Bay, Florida. The site was established in the summer of 1976 and survived for 13 months. The plantings disappeared at the end of the summer of 1977. The reasons for site failure cannot be identified with certainty, although several possibilities are discussed.

3. Limitations of time and priority prevented thorough exploration of the aquatic habitat development alternative within the DMRP. Work Unit 4E03 is one of only two work units within Task 4E. The report from the other work unit, 4E01, presented the results of an extensive literature survey on seagrasses. The literature survey provided a necessary first step in the evolution of a new research area. The pilot field study established initial feasibility. These research items indicate that habitat development on submerged dredged material disposal sites is promising, but largely untested.

John L. Cannon
JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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Transplants of shoal grass (*Halodule wrightii*) at Port St. Joe, Florida, indicate that it may be feasible to propagate seagrass on dredged material. Using the plug technique, two sizes of plugs were removed from a natural meadow and planted on coarse-grained dredged material at three different spacing intervals. Many of the transplants demonstrated a significant amount of growth before the project failed nearly 13 months after planting. Best growth was obtained with 375-cm^2 plugs planted on 0.9-m centers. The cont

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reason for the project failure is not known, but it is hypothesized that the factors involved included stresses from an unusually cold winter, exposure, erosion, sedimentation, variations in water quality, and heavy surf. While the study indicates that seagrass propagation on dredged material has promise, further field study is needed.

SUMMARY

Seagrasses are a valuable component of the aquatic ecosystem because of their high productivity, ability to stabilize sediments, role in nutrient cycling, and provision of food and shelter for marine organisms. Seagrasses, because of their coastal location, are vulnerable to disruption by dredging activities; for this reason, developing techniques for their propagation is becoming increasingly important.

This report describes the results of an effort to establish shoal grass (*Halodule wrightii*) on subaquatic, unconfined, coarse-grained dredged material near Port St. Joe, Florida. Shoal grass was chosen for its suitability to local substrate conditions and because of its tolerance to environmental extremes. The propagation technique involved removing two sizes of plugs, 177 and 375 cm^2, from a natural bed and planting them on 0.9-, 1.8-, and 2.7-m centers in two replicate plots. Survival, growth, and production of the plantings were monitored for 13 months.

During the study period, the site experienced extremes in exposure and cold, was subjected to erosion and siltation, and was continuously bathed by effluents from swamps and a paper mill. These factors appear to have operated in some combination to weaken the plantings. Although the rate of survival declined, survivors grew well and were spreading until they were destroyed by heavy surf in late summer 1977.

The investigation indicated that propagation of shoal grass on dredged material merits further consideration. It is recommended that 375-cm^2 transplant plugs be planted on 0.9-m centers at a depth of 0-1.0 m below mean low water.

PREFACE

This report describes a study of seagrass propagation on dredged material in St. Joseph Bay on the Gulf coast of Florida. The study was conducted as part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Task 4E, "Aquatic Habitat Development," of the Habitat Development Project (HDP).

The DMRP Civil Works Program is sponsored by the Office, Chief of Engineers (DAEN-CWO-M), and is assigned to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, under the administration of the Environmental Laboratory (EL).

Planting and monitoring of the site was conducted by HDP personnel and Dr. Ronald Phillips of Seattle Pacific College, Seattle, Washington (Contract No. DACW39-76-C-0170, Work Unit 4E03). The contract was managed initially by Dr. Luther Holloway and later by Dr. Robert T. Huffman, HDP. The study was conducted under the general supervision of Dr. Hanley K. Smith, Manager, HDP, Dr. Roger T. Saucier, Special Assistant, DMRP, and Dr. John Harrison, Chief, EL.

This report was written by Drs. Phillips and Huffman and Ms. Mary K. Vincent. Drafts of the report were critically reviewed and edited by Dr. Richard A. Cole of the Natural Resources Development Branch, EL, and of the Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan.

The Commander and Director of WES during the period of study and report preparation was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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Summary Report

PART I: INTRODUCTION

Background

1. The Dredged Material Research Program assigned to the U. S. Army Engineer Waterways Experiment Station in 1973 was undertaken in response to increased national concern for the environmental effects of dredging activities. The overall objective of the Dredged Material Research Program summarizes the nature of the problems confronted as well as the Program's major project areas:

> To provide, through research, definite information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource.

2. One of the primary efforts of the Program was to assess the feasibility of developing habitat on dredged material substrate. To accomplish this the Habitat Development Project conducted several field studies in marsh, island, upland, and aquatic habitats. In the studies of aquatic habitat development, the specific goal was to demonstrate and evaluate the environmental, economic, and engineering feasibility of using dredged material as a substrate for aquatic habitat development.

Problem

3. Dredging and disposal activities in shallow coastal areas often destroy seagrass beds and so eliminate shelter areas and food resources for many associated organisms. If extensive, the loss of the beds can impact commercial activities, e.g., shrimp disappeared in Florida in areas where seagrass beds were dredged (Dzurik 1975).

Natural recovery of seagrass is site specific, and depending on the circumstances, the beds may never recover. For further understanding of the problem, the value of seagrass and the stresses caused by dredging are briefly reviewed in the following paragraphs.

Value of seagrasses

4. The importance of seagrasses to aquatic ecosystems is evidenced by their high productivity, ability to stabilize sediments, role in nutrient cycling, and provision of food and shelter. Seagrass productivity by the plants alone is about 5 to 15 g C/m^2 per day, while attached algae and phytoplankton may raise that to more than 20 g C/m^2 per day (McRoy and Helfferich 1977). Their colonial growth habit and dense root systems enable seagrasses to effectively stabilize sediments. That established beds are rooted strongly enough to resist uprooting by hurricanes indicates their value in coastal protection. There is evidence that some seagrass communities provide an important biogeochemical pathway for movement of phosphorous and nitrogen from the sediment to the water column (McRoy and Barsdate 1970, McRoy et al. 1973). This nutrient cycling may foster growth of attached algae uneven in nutrient-poor water (McRoy and Goering 1974). Because seagrasses often provide a significant habitat for attached algae, they indirectly provide food for many small marine animals that are eaten in turn by commercially and recreationally important animals. Seagrass also forms the basis of many detrital food chains. Among animals that graze directly on living seagrasses are manatees, sea urchins, some fishes and turtles, and waterfowl. As shelter and nursery, seagrasses provide protection for several commercial fishes and shrimp during at least a protion of their life cycle; other organisms such as clams may be sheltered throughout their life (Hartog 1977).

Dredging stresses

5. Being shallow water plants, seagrasses are vulnerable to stresses caused by dredging activities: they may be removed by dredging, smothered by disposal, or adversely affected by the short-term increase in turbidity. Dredging not only uproots the plants but may prevent later recolonization if the resulting water depth becomes too great to allow

sufficient light penetration. While seagrasses have some ability to withstand disposal, no species is likely to survive burial under more than 30 cm of sediment (Odum 1963). Besides direct smothering, disposal may preclude seagrass growth by creating overly shallow depths or unconsolidated substrates. The temporary increases in turbidity, which accompany dredging and disposal, may stress or eliminate seagrasses by reducing light penetration.

Purpose and Scope

6. Since seagrasses are a valuable component of the aquatic ecosystem, restoration or establishment of seagrass beds is desirable. In particular, seagrass propagation offers a promising solution to some dredging problems encountered in shallow coastal bays and estuaries where unstable islands and subaquatic disposal banks are formed from disposed dredged material. Establishing seagrass communities on these areas could stabilize them and augment productivity and habitat diversity in coastal environments.

7. This report describes the results of an effort to propagate seagrass on a subaquatic disposal bank near Port St. Joe, Florida. The study involved transplanting a pioneer species of seagrass and monitoring plantings in order to assess the feasibility of using dredged material substrate for the development of seagrass bed habitat. Survival, growth, and production of two sizes of transplants planted at three spacing intervals were monitored for 13 months.

Rationale

8. Seagrass transplantation is gaining acceptance as a solution to redeveloping beds that have been destroyed by human activities. There are two basic techniques by which seagrasses are propagated: transplants and seeds. Transplants may consist of plugs (which include sods or turfs), turions (individual leaf shoots without rhizomes), rhizomes, or seedlings. Transplants may be unanchored, or where washout

may be a problem, they can be anchored by various means including rods, mats, cans, or concrete blocks. A more complete discussion of seagrass transplantation techniques is given in Phillips (1974).

9. Living plant material is preferable to seed since it is usually available all year. Seeds have disadvantages of unpredictable availability and viability and low rate of survival after germination. However, Thorhaug (1974) has described excellent success in seeding turtle grass (*Thalassia testudinum*) under certain conditions.

10. The plug transplantation technique was selected for this study because plant material was readily available in a nearby bed and because general experience has shown that this method gives the best results (Phillips 1974), Ranwell et al. 1974, van Breedveld 1975). The advantages of plugs are that the rhizome-sediment interface is undisturbed and the original sediment serves as an anchor for the transplanted material.

PART II: SITE DESCRIPTION

11. Port St. Joe is located on the northwest coast of Florida within St. Joseph Bay (Figure 1). The bay is separated from the Gulf of Mexico by St. Joseph Spit. The mainland area is composed predominantly of poorly drained lowland swamps and marshes. Bay depths range to about 9 m and the bottom is composed mostly of compacted sands and finer grained materials known as hardoruds. One of the best natural harbors on the Gulf, Port St. Joe has as its major industries a large

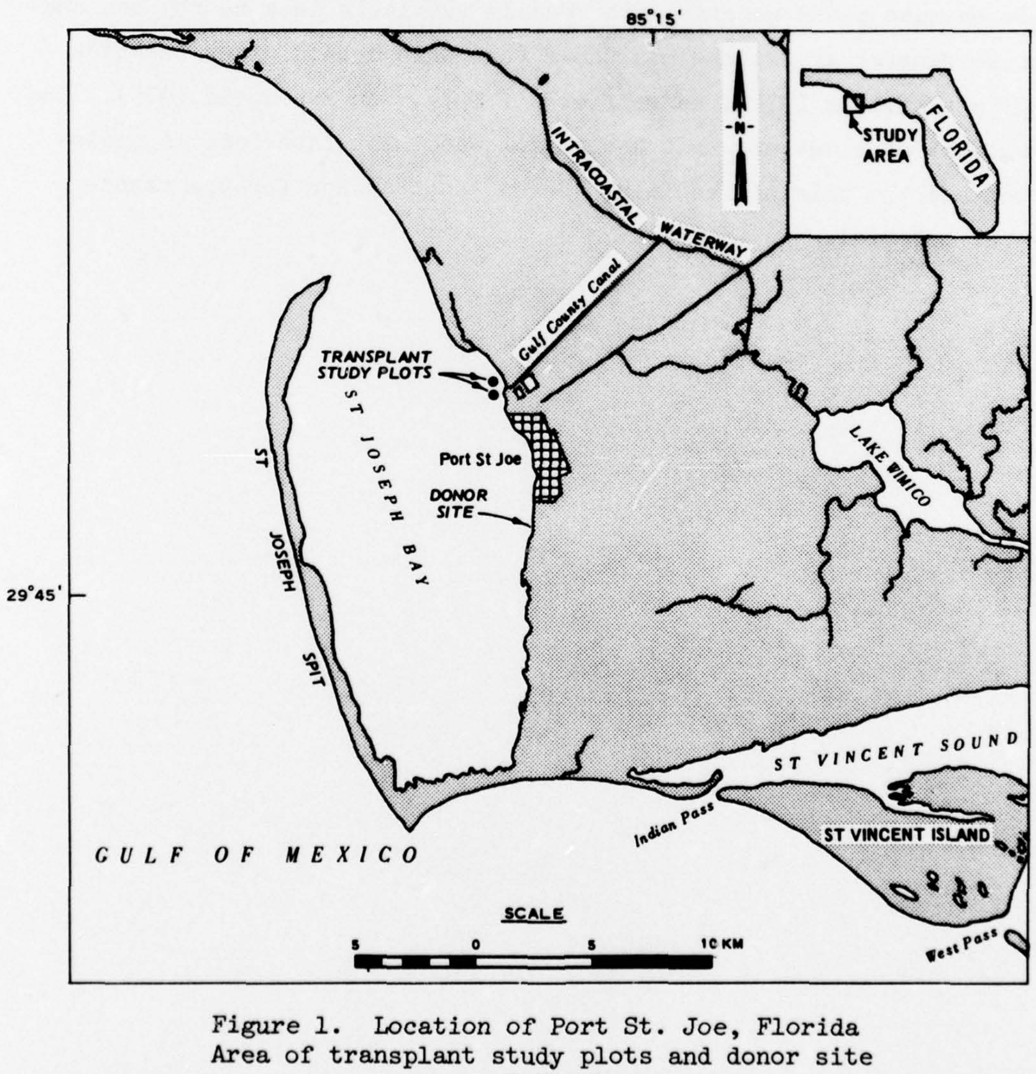

Figure 1. Location of Port St. Joe, Florida
Area of transplant study plots and donor site
are indicated

papermill on the waterfront and two chemical plants situated adjacent to the Gulf County Canal. The bay receives effluent from these industries as well as from small commercial fish processing houses, a wastewater-sewage treatment plant, and swamps.

12. The climate is subtropical. At the closest weather recording station of Apalachicola, Florida, 32 km away, the mean annual temperature is about 20.4°C and the average annual rainfall is about 142.2 cm (Water Information Center 1974). January temperatures average about 12.8°C and July temperatures about 27.4°C. Normally, only five days per year have a minimum temperature below freezing. Occasional cold waves may bring temperatures as low as -10°C. Months with greatest rainfall are July, August, and September, which coincide with the tropical storm season. Except during severe storms the St. Joseph Spit protects the bay from high energy conditions. The mean tide level at Port St. Joe is 0.2 m. The tide is chiefly diurnal with a range of approximately 0.4 m.

13. During the study period surface water salinities in the vicinity of the site varied from about 20-35 ‰.* At the site, salinities were reduced due to freshwater inflow from the Gulf County Canal; at the entry into the bay, salinities sometimes fell to about 5 ‰. At the study area, pH values ranged from about 7.1 to 8.4, while offshore values varied from about 7.5 to 8.5. Turbidity was generally higher in the study area (3-18 JTU) than in the bay (2-11 JTU). Suspended solids (5-20 mg/ℓ) were nearly the same or slightly higher inshore with a high ranging between 30-40 mg/ℓ at the site during summer months.

14. Based on sediment analysis, the substrate at the study site was brackish, generally coarse grained, and low in organic matter, cation exchange capacity, and available nutrients. Coarse-grained sediments (32 to 500 μ) comprised 85 to 96 percent of the substrate, and organic carbon ranged from 0.17 to 0.33 percent. As would be expected for these conditions, the cation exchange capacity was very low (0.25 to 0.59 meq/100 g). Substrate salinity levels were low, ranging from

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* Data on water quality was obtained from the City of Port St. Joe, Wastewater Treatment Plant. Range values given in the text are for the period from 21 July 1976 to 31 August 1977 and are inclusive for the study period.

2.88 to 5.31 $^{o}/_{oo}$; pH ranged from 6.90 to 8.08. Concentrations of orthophosphate and ammonium, nitrite, nitrate, and organic nitrogen were all very low. All samples contained measurable quantities of sulfides.

15. The bay supports a rich biological resource. Seagrasses cover a large part of the bay's lower tidal zone and in some places are growing well out into the bay. Both turtle grass and shoal grass (*Halodule wrightii*)* occur but turtle grass is the dominant species. Adjacent vegetation is largely salt marsh, which exhibits a zonation of species: from lower to higher water levels smooth cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), saltgrass (*Distichlis spicata*), and saltmeadow cordgrass (*Spartina patens*) dominate.

16. St. Joseph Bay is noted for its highly productive scallop beds (*family Pectinidae*). Other commercially fished invertebrates include the blue crab (*Callinectes sapidus*), white shrimp (*Penaeus setiferus*), brown shrimp (*P. duorarum*), and to some extent oysters (*Crassostrea virginica*). Some of the more common commercial fish in the area include Spanish mackerel (*Scomberomorus maculatus*), red snapper (*Lutjanus campecheanus*), black or striped mullet (*Mugil cephalus*), and spotted seatrout (*Cynocion nebulosus*). The bay region provides resting areas for many migratory birds; particularly notable are the sharp shinned hawk (*Accipta striatus*) and broad-winged hawk (*Buteo platypterus*). Common shore and wading birds include gulls, terns, egrets, and herons.

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* Seagrass researchers almost unanimously agree that the species of *Halodule* in the Gulf of Mexico is *Halodule wrightii* (Phillips et al. 1974).

PART III: METHODS AND MATERIALS

Site Selection

17. During the spring of 1976, dredged material disposal areas along the west coast of Florida were considered as potential sites for this study. A site was selected, which included two disposal locations, one on either side of the Gulf County Canal, near Port St. Joe (Figure 1). The Port St. Joe site came closest to satisfying site criteria for optimum seagrass habitat: (a) a sandy substrate with minimal silt accumulation, (b) a maximum water depth of 1.0 m, (c) a low turbidity, (d) low wave energies, (e) salinity between 20 and 40 °/oo, and (f) a nearby source of transplant material.

Species Selection

18. For use in this study, species of seagrass were evaluated with respect to the following criteria: ability to withstand the stresses of pioneer colonization, demonstrated ability to grow on unstable, sandy, and aerobic substrate, and tolerance variations in salinity and to exposure during low tide. The criteria were best met by shoal grass. Among species of seagrass, shoal grass grows closer to the beach, can tolerate higher water temperatures and prolonged exposure to air during extremes in low tide (Humm 1956 and can tolerate salinities of 0 to 60 °/oo (based on observations by Phillips). Shoal grass also has been identified as a primary pioneer species on aerobic substrates (van Breedveld 1975). Furthermore, Eleuterius (1974) indicates that of the Gulf coast seagrass species, shoal grass has the greatest number of roots and rhizomes per unit area, the fastest growth rate, and can be expected to establish most quickly and successfully from transplants. Finally, because of its shallow rhizomic root system, shoal grass is well-adapted for colonization and growth on shifting substrates and so appeared well-suited to the study site.

Experimental Design

19. A portion of each of the two dredged material disposal locations was designed as a 54- by 63-m study plot in August 1976 (Figure 2). Both plots had approximately the same substrate and elevational characteristics. While the sites were approximately level, the 54-m plot length normal to shore allowed for an investigation of differences in water depth and tidal exposure.

20. In order to study the effect of plug size and transplant spacing on the rate of shoal grass colonization, two sizes of plugs and three spacing intervals were used. Large plugs (375 cm^2) were rectangular and measured 15 by 25 cm, while the small plugs (177 cm^2) were cylindrical and measured 15 cm in diameter. Transplants were spaced at 0.9-, 1.8-, and 2.7-m intervals.

21. The two main plots (plots 1 and 2) were planted identically as to plug size and planting interval. Three subplots (A, B, and C), spaced 9 m apart, and running normal to the shore were laid out within each main plot (Figure 3). Subplot A was planted with plugs at 0.9-m intervals, subplot B at 1.8-m intervals, and subplot C at 2.7-m intervals (Table 1). Large plugs were planted in row 1 of subplot A and in rows 1 and 2 of subplot B. Small plugs were planted in the remaining three rows of subplot A, the remaining six rows of subplot B, and in all 12 rows of subplot C (Table 1). A total of 744 plugs were planted within each plot for a total of 1488 for the study.

Transplanting Procedures

22. The two study plots were planted on 2 and 3 August 1976. Plugs of shoal grass were removed from a luxuriant seagrass meadow on a sand shoal near the shore about 6 km from the study site (Figure 1). The donor site was selected because its sandy, aerobic substrate most closely approximated conditions at the study site. In order to study recovery of the donor site, plugs were taken at spacings varying from about 15 to 100 cm.

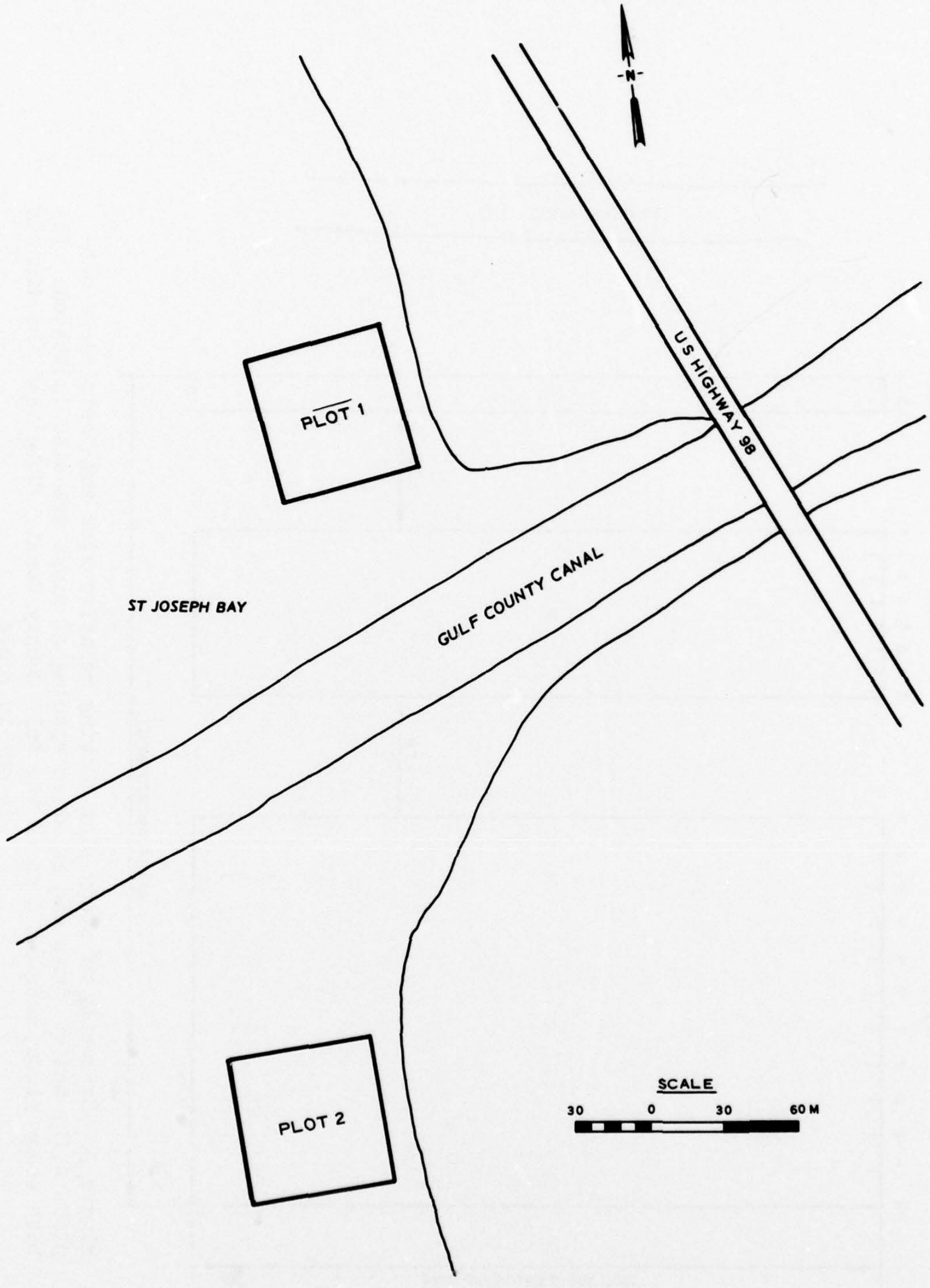

Figure 2. Location of plots planted with shoal grass plugs at Port St. Joe, Florida

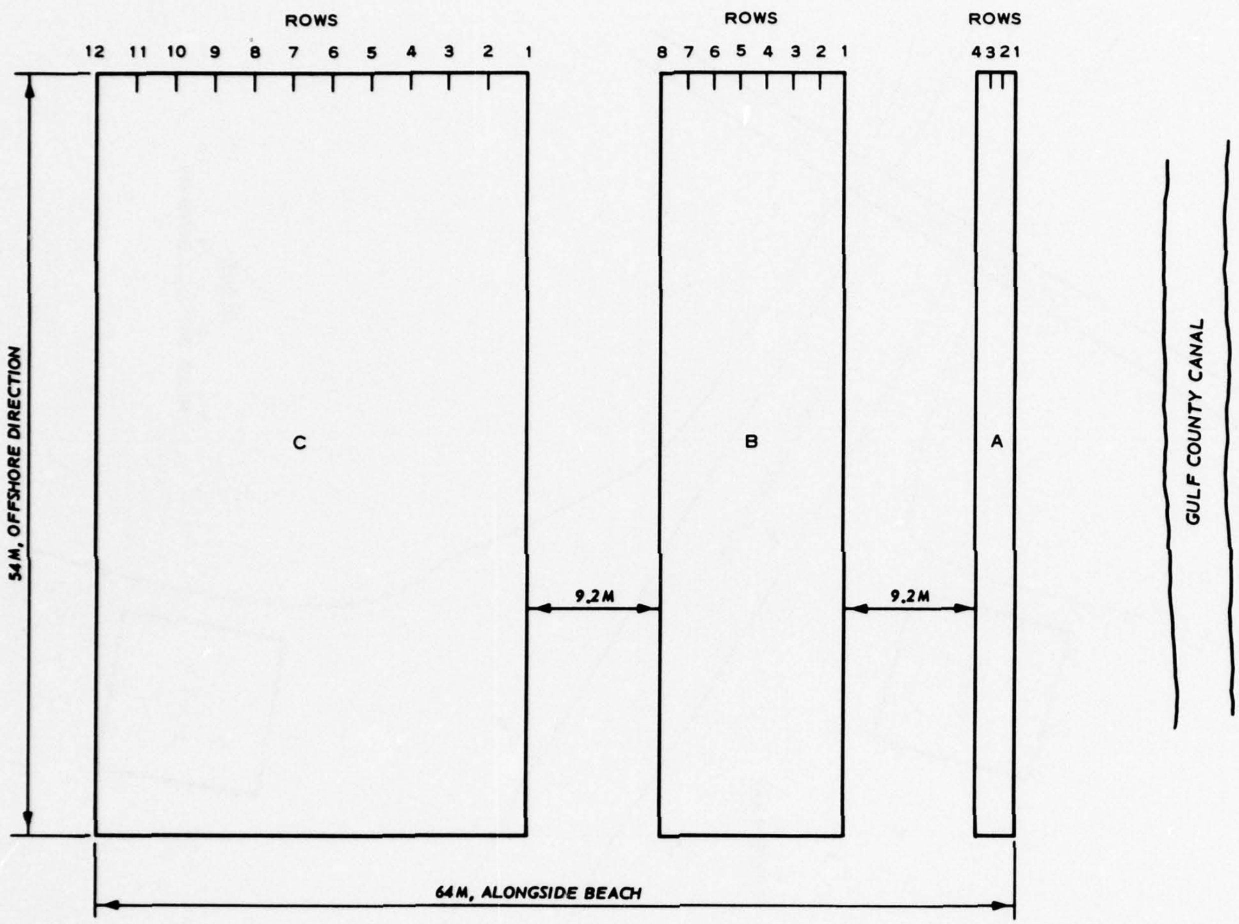

Figure 3. Schematic of study plot showing relative size and position of subplots A, B, and C. Rows and relative spacing of plugs are also indicated. In both study plots, subplot A faced the Gulf County Canal. Note that the diagram is not to scale

Table 1

Details of Planting Design Used in Both Study Plots

Subplot	Dimensions m	Number Rows	Number plugs per Row	Total Plugs	Plug Spacing m	Plug Size in Row and Number Planted: Small 177 cm^2	Number	Large 375 cm^2	Number
A	2.7 × 54	4	61	244	0.9	Rows 2-4	183	Row 1	61
B	12.6 × 54	8	31	248	1.8	Rows 3-8	186	Rows 1,2	62
C	29.7 × 54	12	21	252	2.7	All 12 Rows	252	--	--
				744			621		123

23. Two different sizes and shapes of coring devices were used to obtain the 1488 plugs. For the 1242 smaller plugs (177 cm^2), a cylindrical 15-cm polyvinyl pipe, constructed at WES, was used. The 246 larger plugs (375 cm^2) were removed with a 15- by 25-cm iron frame rectangular corer. The rectangular corer was constructed by the senior author; the design was based on a similar device described by Ranwell et al. (1974). During coring, a shovel was used to carefully slice the plug and surrounding sediment free from the bottom sediment under the corer. The depth of coring by each device was about 15 cm and was sufficient to obtain the entire shoal grass rhizome, which generally grows to only about 7 to 10 cm.

24. Following removal, the plants and original substrate were placed intact in plastic containers and transported by boat to the study plots. At the planting site, holes were dug in the dredged material to accommodate the two sizes of plugs. Figures 4 and 5 show photographs of the planting procedure. It took six men about 53 hours (318 man-hours) to obtain and plant the 1488 plugs. At this rate it is estimated that to plant one hectare with plugs at 0.9-, 1.8-, and 2.7-m spacings would require 2180, 555, and 250 man-hours, respectively.

Figure 4. Plugs of shoal grass being removed and placed on boat for transfer to the planting site

a. PVC coring device being used to remove plugs of shoal grass

b. Plugs of shoal grass for transplanting onto dredged material substrate

c. Plugs being planted into sandy dredged material

d. Inspection of plants planted on 3-ft centers

Figure 5. Steps in the planting procedure

Sampling Procedures

Plantings

25. The transplants were monitored on 20-21 January 1977, 30-31 May 1977, and 6-7 September 1977, or 5-1/2, 9-1/2, and 13 months after planting. The variables monitored during each visit included the percent survival of parental plugs, cover, shoot density/m^2, and biomass. Variables were obtained by random sampling of survivors and were recorded for subplot and for plug size within subplot.

26. Percent survival. Parent plugs were considered to be surviving if they were visible. Reported percent survival then is lower than actual survival because while some plugs had been silted over and were no longer visible, they were not necessarily dead. Investigation showed that in many cases the rhizome systems and leafy stalks were still present in the silted-over plugs.

27. Cover. Cover values were determined by centering a 0.01-m^2 frame over a plug and estimating coverage of the frame. Cover was measured on four randomly selected plugs within every row. Measured cover was extrapolated to the area of concern (subplot or plug size within subplot) by calculating the mean of cover per plug in that area and multiplying by the number of surviving plugs in that area. Values were reported as percent cover and as cover/m^2.

28. Shoot density. The 0.01-m^2 frame used for cover was also used to obtain shoot density/m^2. Eight plugs were sampled within each subplot and four within each plug size. Thus, in subplot A, four plugs were randomly selected in row 1 (large plugs) and four over rows 2, 3, and 4 (small plugs). In subplot B, four plugs were randomly sampled in rows 1 and 2 (large plugs) and four over rows 3 through 8 (small plugs). In subplot C, eight plugs were sampled at random from survivors over all 12 rows of small plugs. For each plug sampled, the shoot density value obtained was an average of two 0.01-m^2 samples, i.e., two placements of the frame.

29. Biomass. Samples obtained for analysis of standing crop were the same plugs selected for the shoot density study. Again, two 0.01-m^2

samples were obtained in each plug. Samples were dug, washed, and dried to a constant weight, for 24 hours at 105°C. Total biomass was recorded in g/m^2 for each subplot and for plug size within each subplot.

Substrate

30. In September 1977, sediment samples were collected in plastic bottles. The containers were sealed below the water surface to prevent air from being trapped in the bottles. The samples were then packed in ice and shipped to the San Francisco Bay Marine Research Laboratory, San Francisco, California, for analysis. Samples were analyzed for grain-sized distribution; organic carbon content; cation exchange capacity (CEC); salinity; pH; total Kjeldahl nitrogen; ammonium, nitrite, and nitrate nitrogen; orthophosphates; and sulfides.

PART IV: RESULTS AND DISCUSSION

Site Conditions

31. Observations of site conditions during the monitoring visits are summarized in Table 2. In January 1977, both plots were exposed to air, and ice was 2 mm thick on standing pools inshore and on the dredged material bank. In May, the plots were inundated and blue crabs, fish, snails, and hermit crabs, typically associated with indigenous shoal grass beds, were residing in plot 2. During the September 1977 visit, surf at the site was severe and water was turbid from resuspended sand and silt. Large rafts of seagrass leaves, probably from beds along the St. Joseph Spit, were washing up on the beach.

32. The plants also may have been stressed by lower than normal water levels, extreme winter conditions, and heavy surf. During the fall of 1976 water levels were enough below normal, that portions of the site were exposed almost daily for up to 12 hr daily for several weeks. Exposure was greater at plot 1 than at plot 2 because plantings were generally in shallower water (up to 15 cm shallower). The winter also deviated from normal: at the weather station at Apalachicola (32 km away), December temperatures averaged about 2°C below normal, January temperatures about 5°C below normal, and February temperatures about 3°C below normal (National Climatic Center 1976, 1977a, and 1977b). During December, January, and February, the minimum temperature recorded was -9.4°C and temperatures dropped to freezing or below on twenty-two days. The longest unbroken period of freezing temperatures was six days in January. Prior to the January visit a portion of subplot C in plot 2 eroded away. In addition to this, siltation was occurring all over the site, particularly in subplot C of plot 2. After May, siltation became more uniform over both plots and by the end of the study, in September, silt had accumulated to about 15 to 20 cm. In late August 1977, another event occurred that stressed the plantings. Two hurricanes passed through the northern Gulf of Mexico and for nearly two weeks surf was heavy throughout the area. At Port St. Joe high,

Table 2

Site Conditions During Monitoring Visits

Date	Plot	Time	Tide m	Salinity ppt	Temperature °C		Wind	
					Air	Water	Speed m/sec	Direction
20 Jan 77	1	0900	-0.12	*	-1.0	-1.0	*	*
21 Jan 77	2	0912	-0.09	*	1.25	1.25	*	*
30 May 77	1	1920	-0.06	21.5	*	30.5	*	*
31 May 77	2	2012	-0.09	22.0	*	30.0	*	*
6 Sep 77	1	1633	+0.12	8.0	29.5	27.5	10-13	SE
7 Sep 77	2	1722	+0.12	31.0	29.5	29.0	8-10	SE

* Data not collected.

1.5- to 1.8-m waves prevailed throughout the storm period and tides were 2 to 3 m above normal.

Survival and Growth of Transplants

33. Photographs in Appendix A depict the plantings at the time of the monitoring visits.

Survival

34. Survival was generally high on the first monitoring visit (January 1977, Table 3). Of the 1488 plugs planted, 1162 or 78 percent were visible. Others, not visible, were viable under the sediment surface. Survival was higher at plot 1 than at plot 2 because a portion of subplot C in plot 2 had eroded away. By the second monitoring visit (May 1977), survival in both plots had diminished greatly (Table 3). In plot 1, no plugs in subplots A or B were visible, while in subplot C, only 50 plugs (20 percent) could be seen. Although survival declined, those plugs remaining in both plots were firmly established and spreading. On the third visit in early September 1977, there were no plugs visible on either plot 1 or 2 and further investigation uncovered none that were living. Examination of plugs in subplot C of plot 1 showed that they were actively decomposing.

Cover

35. Despite the unusually cold winter and periodic exposure, many plugs had doubled their coverage by the January visit (Table 4). An increase in cover was measured throughout except in part of subplot C of plot 2, a portion of which had eroded away. Plugs remaining in subplot C had, however, spread well. By May, no plugs were visible in subplots A or B of plot 1 and cover was measured only in plot 2 and in subplot C of plot 1. The data indicate that the only increase in cover occurred in rows 1 and 2 of subplot B, plot 2 (Table 4). Although total cover declined over most plots because of poor survival, it was visually evident that survivors spread well. Spread was particularly good in plot 2 where in several places the plugs were observed to be growing together.

Table 3

Visible Survival of Shoal Grass Transplants

	Subplot A						Subplot B						Subplot C**	
	Row 1*		Rows 2-4**		Overall		Rows 1-2*		Rows 3-8**		Overall			
Date	No. Plugs	%	No. Plugs	%	No. Plugs	%	No. Plugs	%	No. Plugs	%	No. Plugs	%	No. Plugs	%
a. Plot 1														
6 Aug 1976	61	100	183	100	244	100	62	100	186	100	248	100	252	100
20 Jan 1977	56	92	151	82	207	85	56	90	174	94	230	93	225	89
30 May 1977	0	0	0	0	0	0	0	0	0	0	0	0	50	20
6 Sep 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b. Plot 2														
7 Aug 1976	61	100	183	100	244	100	62	100	186	100	248	100	252	100
21 Jan 1977	59	97	169	92	228	93	54	87	119	64	173	70	69	27
31 May 1977	22	36	44	24	66	27	23	37	45	24	68	27	11	4
7 Sep 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Plugs were rectangular, 15 by 25 cm, or 375 cm^2.

** Plugs were cylindrical, 15 cm in diameter, or 177 cm^2.

Table 4

Cover of Shoal Grass Transplants

	Subplot A				Subplot B				Subplot C**	
	Row 1*	Rows 2-4*	Overall		Rows 1 and 2*	Rows 3-8**	Overall			
Date	Total Cover m^2	Total Cover m^2	Total Cover m^2	Percent Cover	Total Cover m^2	Total Cover m^2	Total Cover m^2	Percent Cover	Total Cover m^2	Percent Cover
a. Plot 1										
6 Aug 1976	2.4	3.6	6.0	4.0	2.4	3.6	6.0	0.9	4.9	0.3
20 Jan 1977	3.7	4.3	8.0	5.0	3.8	4.8	8.6	2.4	6.1	0.4
30 May 1977	0	0	0	0	0	0	0	0	2.0	0.1
6 Sep 1977	0	0	0	0	0	0	0	0	0	0
b. Plot 2										
7 Aug 1976	2.4	3.6	6.0	4.0	2.4	3.6	6.0	0.9	4.9	0.3
21 Jan 1977	3.0	5.2	8.2	5.6	2.5	4.8	7.3	1.1	1.3	0.1
31 May 1977	2.7	2.3	5.0	3.4	2.9	2.2	5.1	0.8	1.1	0.1
7 Sep 1977	0	0	0	0	0	0	0	0	0	0

* Plugs were rectangular, 15 by 25 cm, or 375 cm^2.
** Plugs were cylindrical, 15 cm in diameter, or 177 cm^2.

Shoot density and biomass

36. Shoot density in January was high and extremely variable (Table 5). The decline in density within subplots in May accompanied decline in coverage and survival but shoot density within plugs was the same as in January.

37. Biomass values are given in Table 6. January values for the two plots were comparable. In plot 1 it is interesting to note that from January to May standing crop decreased by 33 percent in subplot C (Table 6) even though survival there had decreased by 78 percent (Table 3). This was the result of increased growth by survivors in terms of summer leaf, rhizomes, and roots. In plot 2, the standing crop increased 32 percent from January to May despite a decline in plug survival (69 percent) and coverage (33 percent).

Effect of Transplant Size and Spacing Interval

38. In general, the larger plugs survived and grew better than smaller plugs (Table 7). From January to May, when coverage and survival declined greatly, the larger plugs declined less than the smaller ones. In subplot B of plot 2, the surviving larger plugs exhibited increased spread (Table 7), and in some cases, the larger plugs were growing together and had rhizomes up to 1 m long extending in all directions. The better performance of the larger plugs may be related to the larger food reserves stored in their rhizomes. The larger size seems to enable more rapid establishment and spread and greater resistance to siltation.

39. Both large and small plugs grew best on 0.9-m centers (Table 7). There was no apparent relationship between plug spacing and survival (Table 3) or between plug spacing and value of shoot density and biomass within plugs (Tables 5 and 6); however, plugs on 2.7-m centers were not vere resistant to siltation.

Recovery of the Donor Site

40. The natural seagrass bed that provided the transplants in

Table 5

Shoot Density of Shoal Grass Transplants

(Stems per square meter)

Date	Subplot A			Subplot B			Subplot C**	
	Density Within Plug		Density Within Subplot	Density Within Plug		Density Within Subplot	Density Within Plug	Density Within Subplot
	Row 1*	Rows 2-4**		Rows 1 and 2*	Rows 3-8**			
a. Plot 1								
20 Jan 1977	6800	12,000	526	6900	1500	49	8450	32
30 May 1977	0	0	0	0	0	0	8450	10
6 Sep 1977	0	0	0	0	0	0	0	0
b. Plot 2								
21 Jan 1977	4350	3,150	202	6100	9000	59	4800	4
31 May 1977	4350	3,150	70	6100	9000	41	4800	3
7 Sep 1977	0	0	0	0	0	0	0	0

* Plugs were rectangular, 15 by 25 cm, or 375 cm^2.

** Plugs were cylindrical, 15 cm in diameter, or 177 cm^2.

Table 6

Biomass of Shoal Grass Transplants (Dry Weight, grams per square metre)

	Subplot A				Subplot B				Subplot C**	
	Row 1*	Rows 2-4**	Overall		Rows 1 and 2*	Rows 3-8**	Overall			
Date	Mean per Sample	Mean per Sample	Mean per Sample	Total in Subplot	Mean per Sample	Mean per Sample	Mean per Sample	Total in Subplot	Mean per Sample	Total in Subplot
a. Plot 1										
20 Jan 1977	2.43	2.61	2.52	2016.0	2.31	1.30	1.80	1548.0	2.54	1549.0
30 May 1977	0	0	0	0	0	0	0	0	5.08	1031.2
6 Sep 1977	0	0	0	0	0	0	0	0	0	0
b. Plot 2										
21 Jan 1977	2.41	1.61	2.01	1654.0	2.11	1.65	1.87	1365.0	1.51	196.0
31 May 1977	4.82	3.22	4.02	2018.2	4.22	3.30	3.74	1907.4	3.02	320.0
7 Sep 1977	0	0	0	0	0	0	0	0	0	0

* Plugs were rectangular, 15 by 25 cm, or 375 cm^2.

** Plugs were cylindrical, 15 cm in diameter, or 177 cm^2.

Table 7

Percent Change in Cover by Transplant Size

	Large Plugs				Small Plugs			
	Plot 1		Plot 2		Plot 1		Plot 2	
Time Period	Subplot A Row 1 0.9-m Spacing	Subplot B Rows 1 and 2 1.8-m Spacing	Subplot A Row 1 0.9-m Spacing	Subplot B Rows 1 and 2 1.8-m Spacing	Subplot A Rows 2-4 0.9-m Spacing	Subplot B Rows 3-8 1.8-m Spacing	Subplot A Rows 2-4 0.9-m Spacing	Subplot B Rows 3-8 1.8-m Spacing
Aug 76-Jan 77	+54.2	+58.3	+26.3	+4.2	+19.4	+33.3	+44.4	+33.3
Jan 77-May 77	--	--	-11.2	+16.0	--	--	-55.2	-54.2

August 1976 was visited in January and May 1977 to see the effect of plug removal. By January, the 15-cm-deep holes had completely filled in. In almost all cases, rhizome runners had extended across the open spaces and many of the spaces had been partly covered by spreading shoal grass. By May most of the disturbed areas had been recolonized, but growth was still thinner there than in the undisturbed bed. There remained a few large open spaces resembling blowouts where plugs had been taken at close intervals of about 15 cm. All areas where plugs had been taken no less than 30 cm apart had nearly recovered. These observations indicate that a prudent minimal distance for plug removal would be about 0.5 m.

Possible Reasons for Failure

41. In September 1977, thirteen months after planting, none of the plugs were found to be surviving and all were presumed to be dead. No single cause for the failure can be isolated, but several possibilities exist. Since surviving transplants generally grew and spread well even though the rate of survival decreased, it appeared that the failure was the culmination of a combination of factors, possibly operating at different times. Had the failure been caused by a single agent, then the plantings probably would have died within a short interval of time. Had the failure been caused by a continuously adverse factor, plug survival in January probably would have been lower and plug condition generally unhealthy. Factors that could have operated in some combination to cause the failure are: (a) exposure, (b) the unusually cold winter, (c) the storms of August 1977, and (d) paper mill and swamp effluent.

42. Exposure, with attendant stresses caused by heating and desiccation, was extreme during the fall of 1976. This was followed by exposure to record-cold winter temperatures. Nevertheless, the plugs demonstrated good increase in cover from August 1976 to January 1977. During the four months between the January and May visits the site experienced nearly another month of exceptionally cold temperatures and

continued periods of exposure. The increased mortality seen in May was probably in response to months of exposure and cold, which weakened and finally killed many of the transplants. In plot 1, where exposure was greater, 93 percent of the plugs were dead by May. In comparison, 80 percent were dead in plot 2 but a significant portion of those had been lost to erosion. The natural seagrass beds in the area also suffered from the cold winter: damage and stunting were observed in beds that had been exposed.

43. The heavy surf and wave action from two hurricanes that occurred in the northern Gulf of Mexico in August 1977 may have moved in enough sediment to bury the remaining transplants. Natural beds of seagrass are able to withstand hurricanes because of their dense, matted growth, but the transplants had not yet developed to that extent. Their vulnerability was further increased by the instability of the dredged material substrate. Three months prior to the storms, the transplants on plot 2 that had survived the winter were spreading vigorously. Although some of the transplants could have been washed away, most appeared to have been buried by shifting sediments.

44. Effluent from swamps and a nearby paper mill were visible in the study area as dark brown water. Both plots were bathed by the effluent on ebbing tides but plot 1 appeared to receive more of the discharge than plot 2. The impacts of kraft-mill effluent on benthic macrophytes are not well known, but Zimmerman and Livingston (1976) associated it with significant reductions in macrophyte biomass and numbers of species per unit area. Kraft-mill effluent shows no evidence of having a herbicidal effect; instead, the major impacts appear to be from alterations in water quality including reduced light penetration, caused by elevated color and turbidity, and from fluctuation in salinity, caused by freshwater flushing of the effluent (Zimmerman 1974, Zimmerman and Livingston 1976). With regard to the transplants at Port St. Joe, effluent from the paper mill was a constant factor and may have inhibited plant growth. In plot 1, which was most affected, the effluent may have contributed to reduced survival but it is not suspected of having a major impact since some plants survived and grew

well for many months. In addition, there are native beds that withstand the effluent with no ill effects.

PART V: CONCLUSIONS AND RECOMMENDATIONS

45. The seagrass transplantation effort undertaken in this study demonstrates that shoal grass transplants will survive and grow on dredged material and that the technique has potential for development of seagrass beds. Although the plantings eventually failed, the results provided valuable insight into the problems that may be encountered. Despite extremes of exposure and cold, many of the transplants exhibited excellent growth and in some cases plugs grew together. Throughout the study, shoal grass demonstrated remarkable tolerance to adverse conditions. If the site had had normal climatic conditions during the study period, the transplants might have become successfully established. However, this is conjecture and could only be determined through further study.

46. The transplants succumbed to some combination of factors that included the following possible stresses: exposure to air and desiccation, record-cold winter, heavy surf and siltation, and exposure to swamp and paper mill effluent. Exposure to air and paper mill effluent were greater at plot 1, while surf and siltation were greater at plot 2.

47. Based on the results of this study shoal grass transplants are tentatively recommended for futher consideration for development of seagrass beds on coarse-grained dredged material. For best chance of success, the transplants should be planted at depths between mean low water to about 1 m or more below. It is recommended that the larger plugs (375 cm^2) be used and spaced at 0.9-m intervals. Even under the adverse conditions that materialized in this study, the larger plugs on 0.9-m centers had nearly coalesced into continuous cover in less than a year. If transplant stock, funds, or time are limited, than 375 cm^2 plugs could be planted on 1.8-m centers but coverage will be slower. The smaller plugs (177 cm^2) are not recommended. In digging the plugs from a donor bed, a space of at least 0.5 m should be left between removals.

48. The findings of this study should be considered with care:

while good results were realized until the site failed, long-term results were not obtained. Much of the performance evaluation is based on qualitative observation and needs additional testing. Furthermore, the discussion of reasons for failure is hypothetical and based on assumptions; the actual cause(s) remain uncertain.

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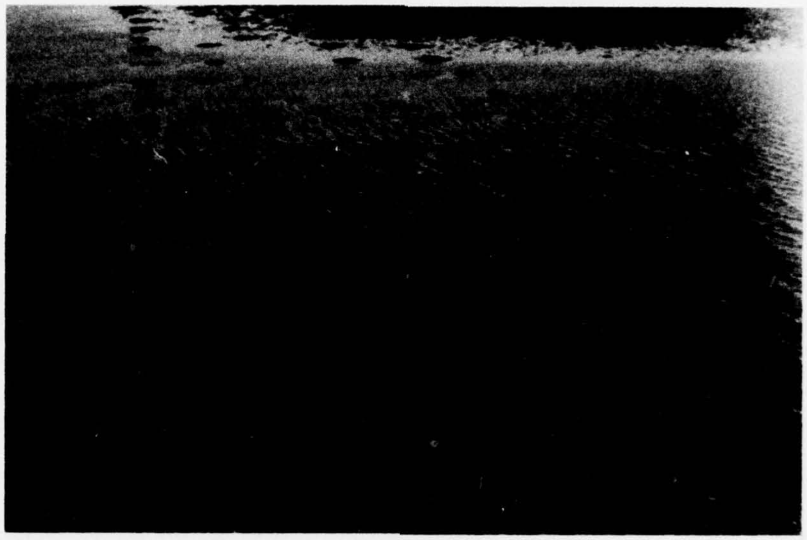
APPENDIX A: PHOTOGRAPHS OF SHOAL GRASS TRANSPLANTS

Note: Frames in photographs have areal coverage of $0.01 \ m^2$.



a. Overview

b. Small Plug (177 cm^2)

Photo 1. 20 January 1977, plot 1, subplot A (0.9-m centers) (sheet 1 of 2)

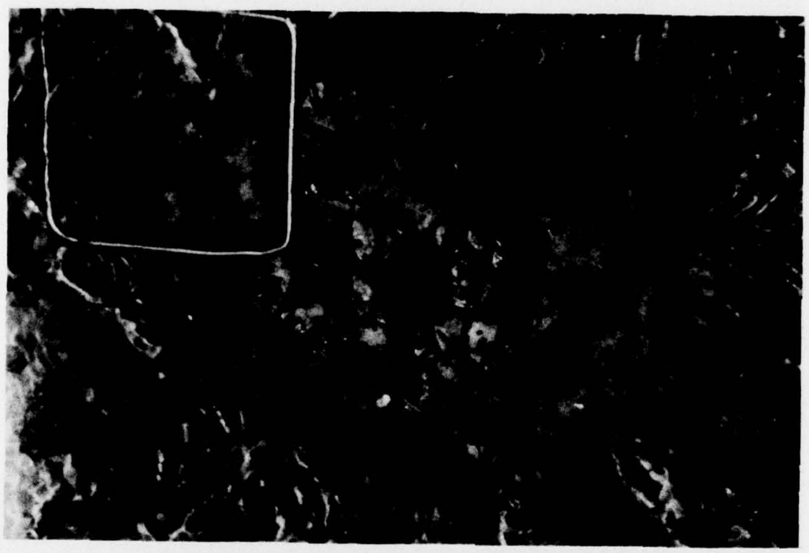
c. Large plug (375 cm^2)

Photo 1 (sheet 2 of 2)

a. Overview

b. Small plug (177 cm^2)

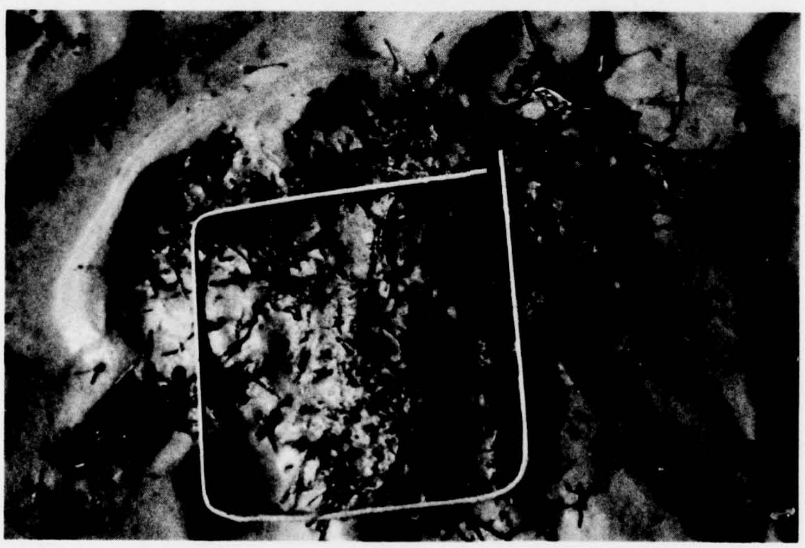
Photo 2. 20 January 1977, plot 1, subplot B (1.8-m centers) (sheet 1 of 2)



c. Large plug (375 cm^2). Note rhizome and plant extensions at upper left and upper right

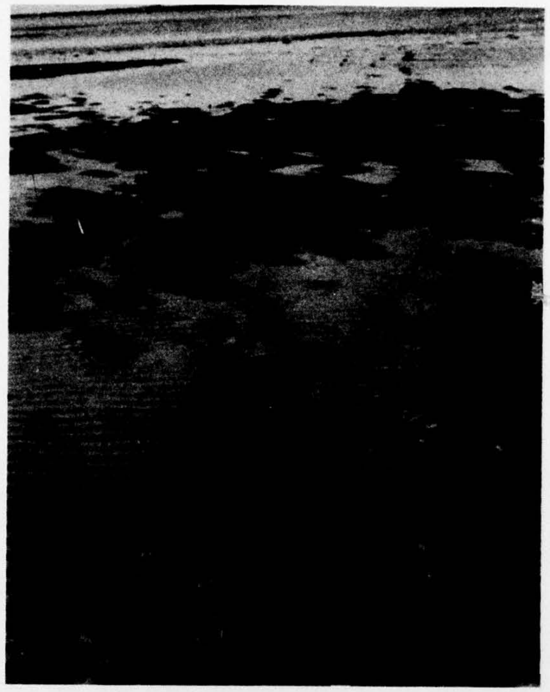
Photo 2 (sheet 2 of 2)

a. Overview

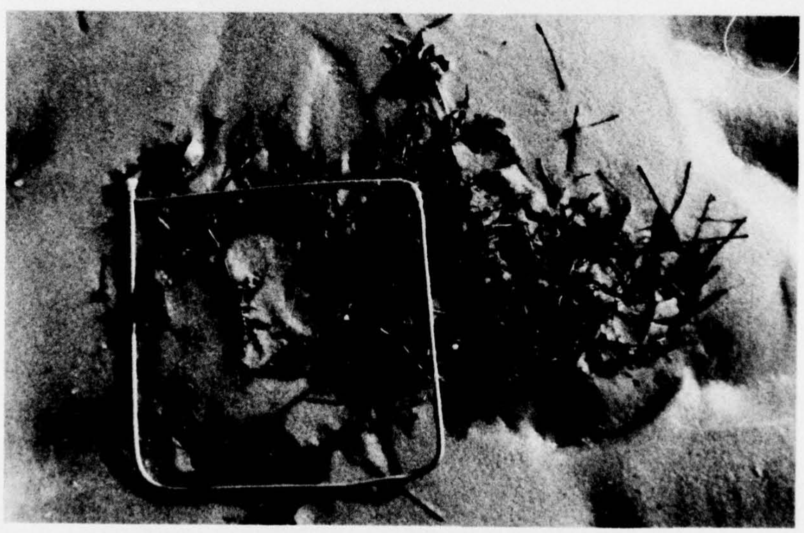


b. Small plug (177 cm^2). Note rhizome extension and plant extension at lower left and right

Photo 3. 20 January 1977, plot 1, subplot C (2.7-m centers)

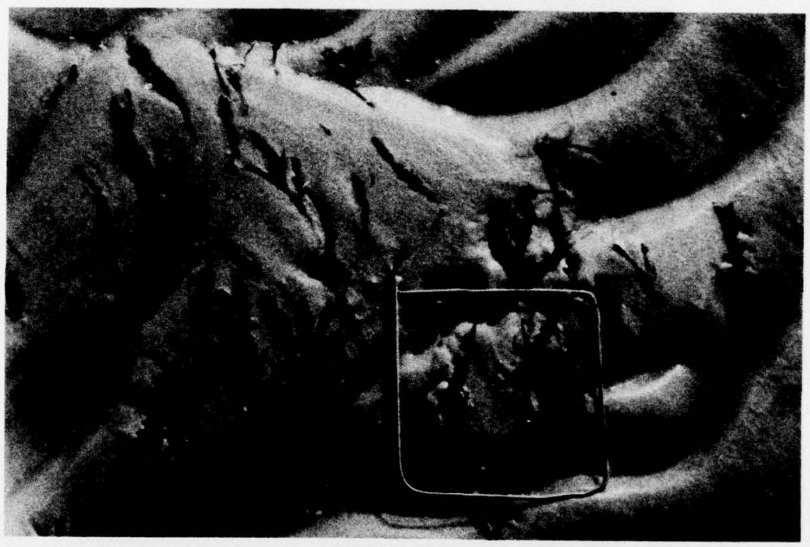


a. Overview



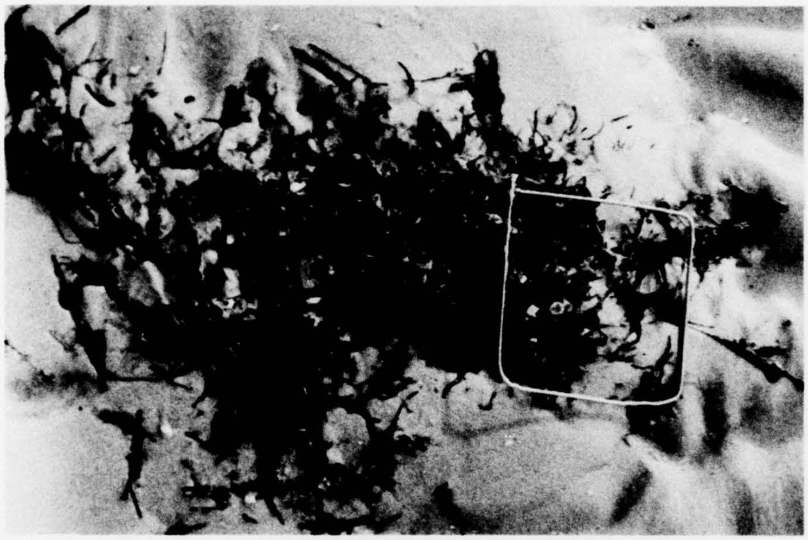
b. Small plug (177 cm^2)

Photo 4. 21 January 1977, plot 2, subplot A (0.9-m centers) (sheet 1 of 2)

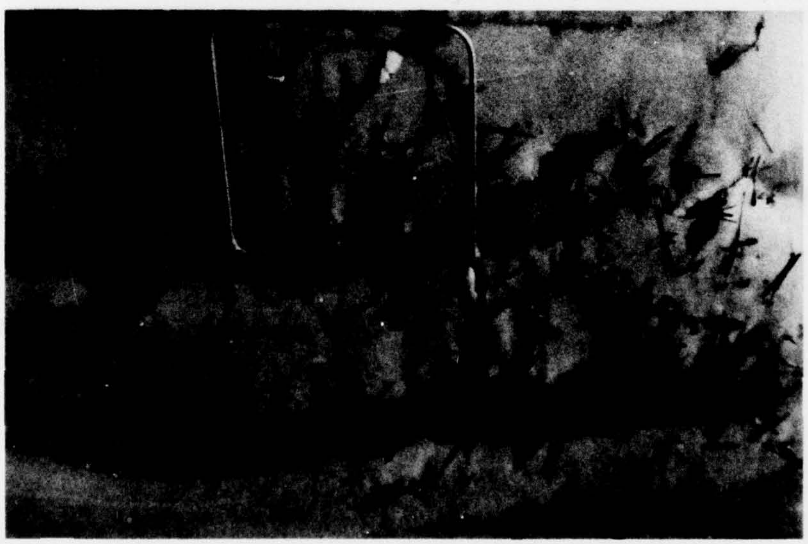


c. Small plug (177 cm^2) showing siltation

Photo 4 (sheet 2 of 2)

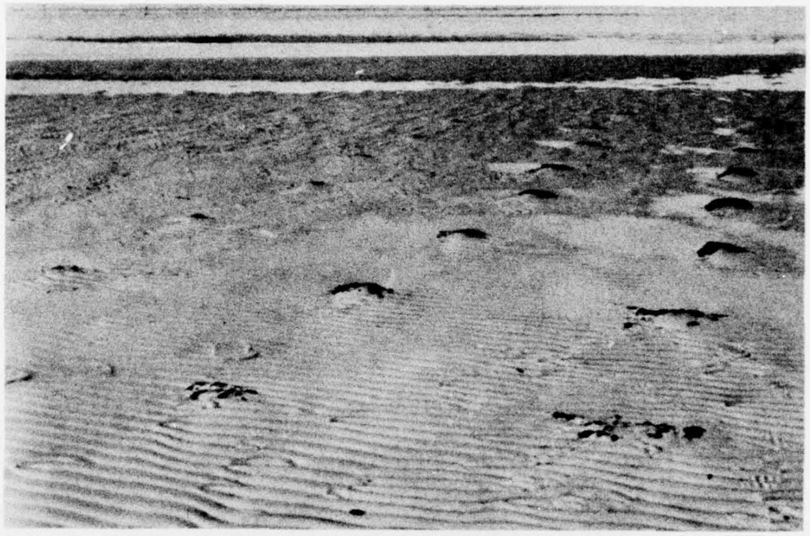


a. Large plug (375 cm^2). Note rhizome extension at upper left



b. Large plug (375 cm^2) showing siltation

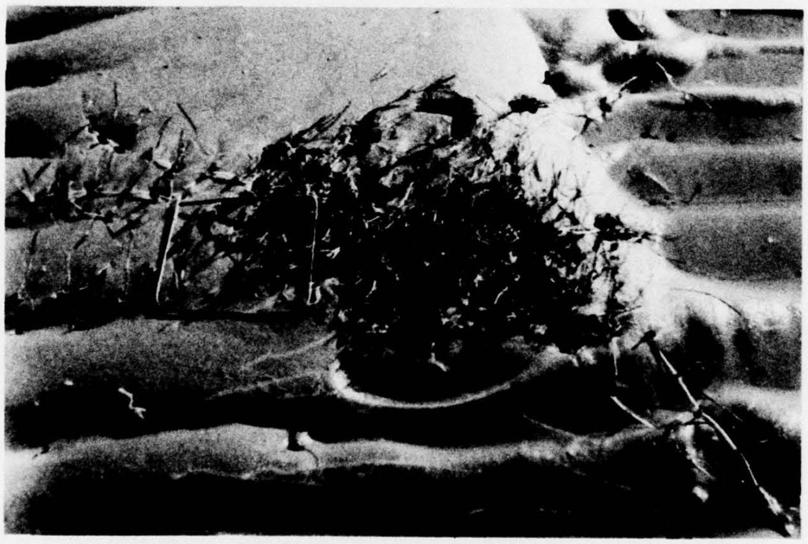
Photo 5. 21 January 1977, plot 2, subplot A (0.9-m centers)



a. Overview

b. Small plug (177 cm^2)

Photo 6. 21 January 1977, plot 2, subplot B
(1.8-m centers) (sheet 1 of 2)



c. Large plug (375 cm^2). Note rhizome extension at lower right

Photo 6 (sheet 2 of 2)

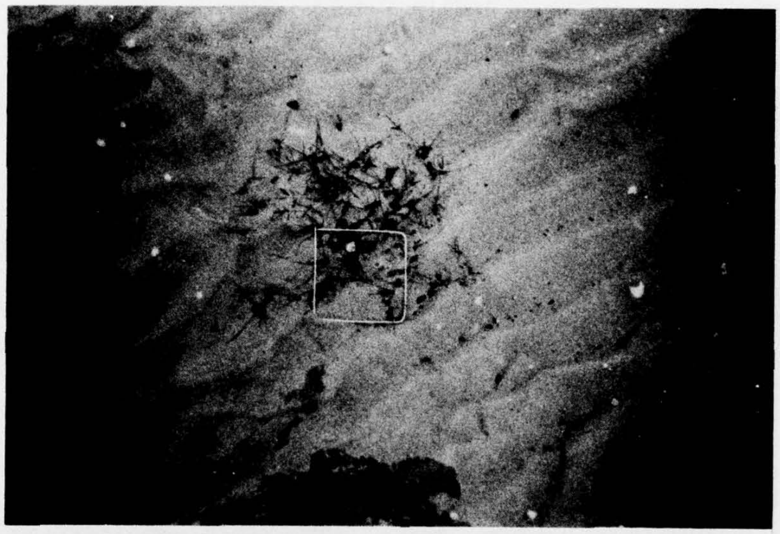


Photo 7. 30 May 1977, plot 1, subplot C (2.7-m centers),*
small plug (177 cm^2)

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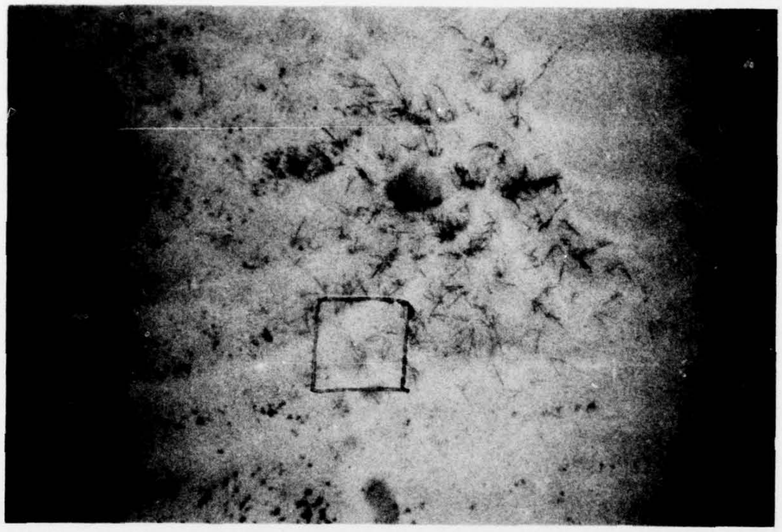
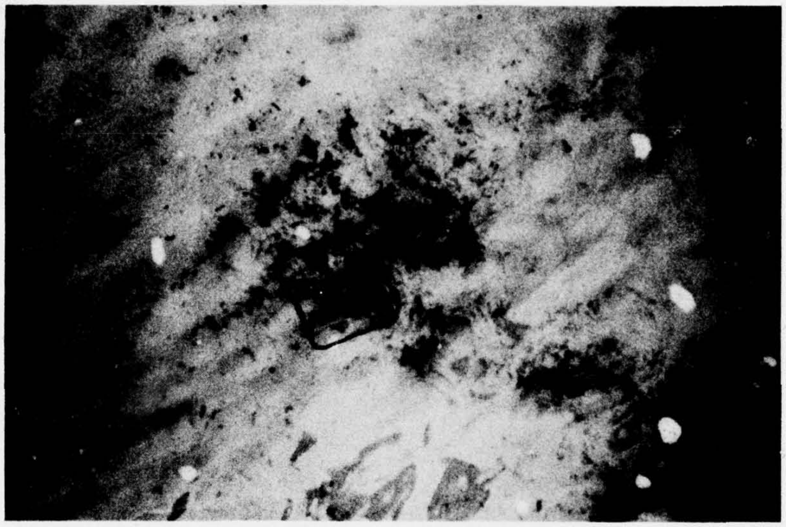
* No plugs visible in subplot A or B.



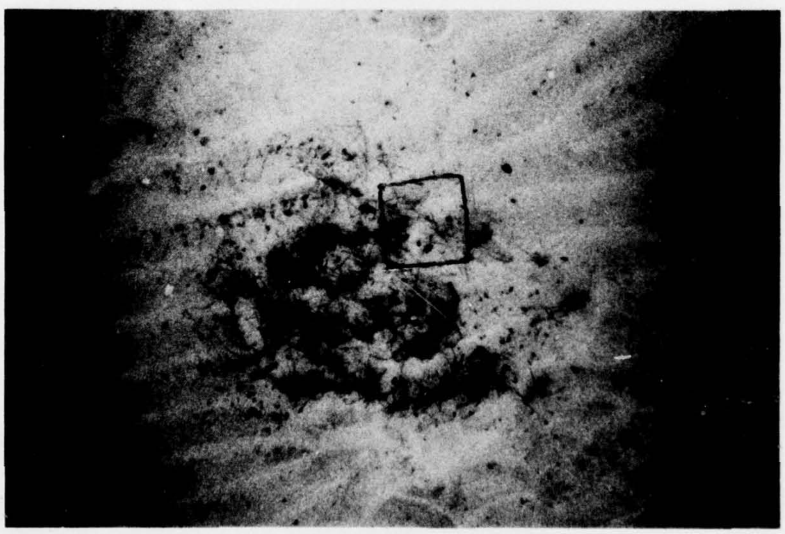
a. Small plug (177 cm^2)

b. Large plug (375 cm^2)

Photo 8. 30 May 1977, plot 2, subplot A
(0.9-m centers)



a. Small plug (177 cm^2). Note two plugs growing together by rhizome extension



b. Large plug (375 cm^2)

Photo 9. 30 May 1977, plot 2, subplot B (1.8-m centers)

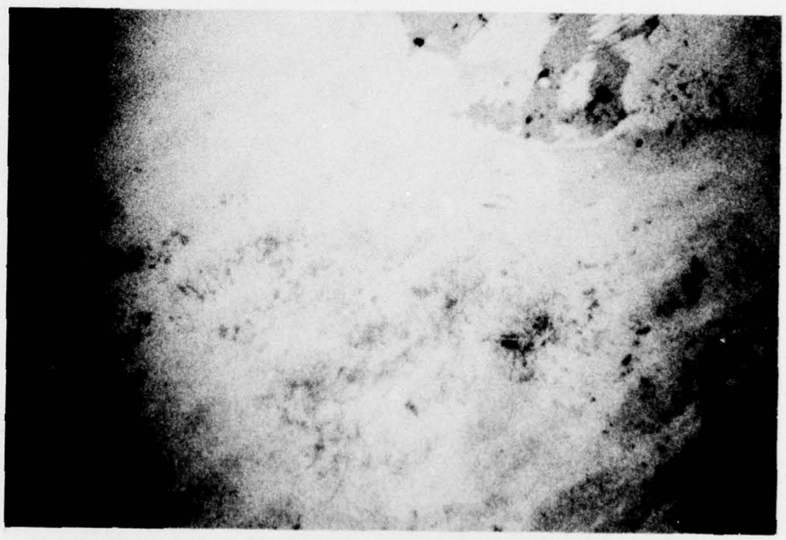


Photo 10. 30 May 1977, plot 2, subplot C (2.7-m centers), small plug (177 cm^2)

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Phillips, Ronald C

Habitat development field investigations, Port St. Joe seagrass demonstration site, Port St. Joe, Florida; summary report / by Ronald C. Phillips, Seattle Pacific College, Seattle, Washington, and Mary K. Vincent, Robert T. Huffman, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

37, 15 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-33)

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